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On the Microscopic Characters of the Crystals of Arsenious Acid. By William A. Guy, M.B. Cantab., Professor of Forensic Medicine, King's College, London.

(Read May 8th, 1861.)

In submitting to your society this paper on the microscopic characters of the crystals of arsenious acid, I have two principal objects in view. I wish, in the first place, to illustrate, by a striking instance, the great value of the binocular microscope as a means of diagnosis; and, in the second place, to give a more exact account than any at present in existence of the crystalline forms assumed by a very important poison. That to render such an account is not a work of mere supererogation, a reference to the descriptions of the crystals given in works of authority would readily prove.

Most authors describe the crystals as regular octahedra, without recognising any other crystalline forms. Some writers, however, speak of the regular octahedron and its modifications, or of forms traceable to the octahedron; and acicular crystals, long prismatic needles, triangular and hexagonal plates, and even tetrahedra, are to be met with in the descriptions of authors.*

I may add that, in illustrated works, the octahedral crystals are usually figured in the form in which they are most readily identified; the less usual positions of the octahedra and the rarer forms and modifications of the crystal being omitted.

The imperfect and somewhat conflicting accounts thus given of the crystals of arsenious acid are, doubtless, to be explained, partly by the difficulty of examining them, whether by lens or microscope, when sublimed, as they were formerly, in thick reduction-tubes of narrow bore; partly to the great variety of lights and shadows presented by the crystals, especially when viewed by transmitted light; and partly to the imperfect relief given to the crystals when examined by the monocular microscope.

* Consult Pereira's 'Materia Medica,' 4th edition, p. 685, in which the tetrahedron is mentioned as one form of the crystal; Miller's 'Elements of Chemistry,' part ii, p. 961, in which mention is made of long prismatic needles, isomorphous with those of oxide of antimony; and Taylor, on 'Poisons,' 2d edition, p. 385, in which equilateral triangular plates are specified. Pereira cites a foreign authority (Wöhler) who found in a cobalt roasting-furnace arsenious acid crystallised in hexahedral plates derived from a right rhombic prism.

The substitution of the modern form of reduction-tube, in which the vapours of arsenious acid are made to pass through a narrow glass tube with thin sides, has made the examination by the microscope more easy; but the simple plan which I suggested about three years since, for obtaining the crystals on a flat surface, has offered still greater facilities, of which it is but natural that I should have largely availed myself. The knowledge of the subject thus obtained may be said to have been completed by the use of the binocular microscope.

The most superficial and cursory examination of the first specimens obtained upon a flat surface sufficed to convince me that very much remained to be done before our knowledge of the true crystalline characters of arsenious acid could be placed on a level with the practical importance of such knowledge. In the first place, it was quite clear that those descriptions which spoke only of the regular octahedron as the one proper form of the crystal were wholly inadequate; and that even those which recognised, not only the perfect crystal, but all the forms traceable to the octahedron were still insufficient. We ought to know what particular forms to look for. Again, it must be interesting, and might be practically important to know something more of the alleged acicular or prismatic crystals, of the triangular and hexagonal plates, and of the tetrahedra, described and figured in Pereira's work. The crystallographer, too, could scarcely abstain from speculating on the possible occurrence among these octahedra of those other members of the regular system, the cube and the rhombic dodecahedron. Some, if not all, of these questions I hope to be able to answer, without proving tedious to those who have not the special interest in this subject which I have myself. Reverting to my early examinations of the crystalline deposits of arsenious acid as obtained on a flat surface, I may state that I encountered many forms and appearances which I was not able to explain to my own satisfaction. When viewed by transmitted light, a large proportion of the crystals wore the appearance of dark squares, a smaller number of dark oblong figures, a still smaller number of long, thick, black lines. These latter, the long lines, I took to be the acicular or prismatic crystals described in books. The dark squares and oblongs were not so readily explained. Then, again, I encountered among the crystals transmitting or reflecting light, in addition to forms which might be merely different attitudes or postures of the regular octahedron, or of the truncated octahedron, or of the lengthened

octahedron, well-formed triangular prisms, terminated at either end by triangular facettes, also twin-crystals or *mácles*, also equilateral triangles resting on half the adjoining triangle as a base. I will not take up your time further by specifying all the forms which at first puzzled and perplexed me. Suffice it to say that, in the full consciousness that I did not understand the things I saw, I determined to turn for awhile from nature on the small scale to art on the large. I procured octahedra of wood, and not being satisfied with them, prevailed on Messrs. Powell, of Whitefriars, to make me the crystals of glass now before you. By studying these large models, placing them in all sorts of positions, and viewing them from different points and in different lights, I was prepared to understand most of the appearances under the microscope. The broader shadows of the transparent glass crystals were reproduced in the small crystals of arsenious acid, and the several postures which I caused the large crystals to assume were recognisable under the microscope. I found that the sublimed crystals adhered to the flat surface of glass by their solid angles, by their edges, and by their faces, as well as in positions less easily described. I also inferred that the dark squares were crystals (octahedra) adhering to the glass by their solid angles, in which position, as my glass model taught me, the play of lights and shadows was such as to occasion confusion and possible darkness. This suspicion, which was strengthened somewhat when I examined the sublimatés by reflected light, became certainty under the binocular microscope. Under that admirable instrument, with reflected light, there are no dark masses, and no obscure forms. The meaning of the dark oblong forms and of the dark lines which I at first identified with the acicular or prismatic crystals of authors did not occur to me till later in my inquiries.

I have mentioned the frequent occurrence of the three-sided prism with bevelled extremities. I do not mean the figure sometimes described as a lengthened octahedron, but a figure having the deceptive appearance of a triangular prism. Was this a distinct crystalline form, or might it not be some aspect of the octahedron? It obviously could not be brought about by any attitude of the whole crystal; but my wooden model, supplied by Professor Tennant, is cut in half by a plane parallel to, and equidistant from, two of its faces, and these two equal halves of the-crystal are made to rotate on each other, so as to show the twin-crystal, or *mácle*. Here, then, without supposing any new form of crystal, there was new material for speculation. I had seen the twin-crystal, or *mácle*, in

almost every specimen I examined. Hence, it was clear that half-crystals were among the possibilities of arsenious acid sublimed. Well, this half-crystal which I was soon encouraged to have made in glass, when placed in a certain position, gave me the precise figure which had perplexed me; it gave also the equilateral triangle with the half adjoining triangle for its base (one of the commonest crystalline forms); also, the half-triangle itself; also the hexagon, and the hexagon tipped with three small, dark, triangular facettes.

Now this appearance of a triangular prism, terminated at each end with an equilateral triangle, is given by the tilting forward of the half-crystal; and just as the whole crystal adhering by a solid angle becomes by transmitted light a dark square, so this half-crystal appears as a dark oblong.

But the long dark lines which I had taken for needles or prisms, what were they? Possibly not distinct and separate crystals, but only deceptive appearances like the dark squares and oblongs. Could they be the forward edges of large deep plates, owing their dark appearance to the same depth of crystalline mass? It was reserved for the binocular microscope to demonstrate this. On examining with this instrument a vast number of specimens, and passing under review thousands and thousands of crystals, I find many large hexagonal plates with their edges thrown forward, but very few prismatic crystals. I also find triangular plates of various thickness, square plates also of varying substance, and a few rhombic and rhomboidal plates. But my catalogue is not yet exhausted. Before I made use of the binocular microscope, I thought that I had encountered one or two cubes; but as the assertion that I had met with cubes was received somewhat incredulously, I looked for them in the field of the binocular with great interest. I found several figures which approached very closely to the cube, and in one instance encountered a perfect cubical crystal. I say this without any sort of hesitation. I have also more frequently met with the rhombic dodecahedron, and its *mâcle,* or twin-crystal. I have not yet seen a tetrahedron; though in one specimen obtained from Scheele's green, and abounding in triangles less symmetrically formed than usual, I thought that I discerned the marks of the tetrahedron. Be this as it may, I am quite sure that this form of crystal should be set down among mere possibilities: I have not seen it in any one of many hundreds of specimens of crystalline deposit obtained from arsenious acid itself, or from the metal arsenic. It is probable that the deep triangular plates, which abound in some specimens, have been taken for tetrahedra.

I have now briefly sketched the course of experiments, ob-

servations, and inferences by which I was gradually possessed of my existing knowledge of these interesting crystalline forms. Something I learnt from actual examination; such, for instance, as the common appearances of the perfect octahedron, and the fact of the existence of plates of various forms, as well as of crystals other than the octahedron. Something more I learnt by inferences drawn from the close examination of models of the crystal and half-crystal, opaque and transparent. I understood at once the twin-crystal, or *mâcle*. I inferred that the equilateral triangle mounted on a half-triangle as its base, the hexagon with three-shaded points, and the triangular prism were merely phases of the half-crystal; and I thought it likely that some of the detached equilateral triangles and some of the hexagons might be explained in the same manner. But I remained quite satisfied with the belief that a considerable number of the long narrow crystals were prisms. I was not quite satisfied of the existence of triangular plates or of hexagonal plates. I spoke doubtfully about cubes, and had not been able to make out the rhombic dodecahedron; and I felt that my views concerning the large part played by the half-crystal, though highly probable, were still only probable. But under the binocular microscope all my doubts were dissipated, all my errors corrected, some surmises confirmed, and most of my inferences justified. That which had been a work partly of observation, and partly of reasoning, became a simple matter of sensation. If there is any one who doubts the value of this form of the microscope, or is disposed to treat it simply as a philosophical toy, I will ask him to examine these crystals with the monocular microscope by transmitted light, and with the binocular microscope by reflected light; and I would especially commend to his attention the crystalline and globular sublimate (crystals of arsenious acid, and globules of metallic arsenic) shown in the capillary reduction-tube. The fine relief and perfect roundness of the tube and its contents is, at one and the same time, a proof of the utility and of the faithfulness of the binocular microscope.

With a view to give completeness to this paper, I will first briefly describe and illustrate by appropriate engravings, corresponding with the large diagrams and models shown at the meeting, the various attitudes and appearances of the entire octahedron and of the half-crystal, as deduced from the study of models of wood and glass,* and then exhibit some

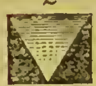
* Since the paper was read, I have added studies of the rhombic dodecahedron, similar to those of the octahedron which were shown in the diagrams exhibited at the meeting. This addition goes far towards exhausting the crystalline forms of sublimed arsenious acid.

of the leading forms as seen under the monocular microscope by transmitted light, and under the binocular microscope by reflected light. I also append, at the desire of the editors of the Journal, a short account of the best mode of obtaining the crystals of arsenious acid for microscopic examination.

1. *The entire crystal.*

1


a. The crystal adhering by one of its edges, and displaying two sides (fig. 1).

2


b. The crystal adhering by one of its faces, and displaying three sides (fig. 2).

3


c. The crystal adhering by one of its faces, and so seen as to display four sides (fig. 3).

4

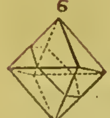

d. The crystal adhering by a solid angle, so as to show four equal faces (fig. 4). In this position the crystals appear by transmitted light as black squares.

5


e. The crystal adhering by one of its faces, and showing the lights and shadows of the transparent model (fig. 5).

2. *The half-crystal.*

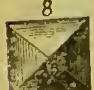
The regular octahedron may be divided into two symmetrical bodies—

6


1. By a plane parallel to two faces of the crystal (fig. 6).

   The sections thus formed are bounded by a hexagon and by an equilateral triangle, and they have the appearance shown in fig. 7.

7


8


2. By a plane passing through four edges of the crystal, each section being a four-side pyramid on a square base (fig. 8).

9


3. By a plane cutting the equilateral triangular faces of the crystal into two equal right-angled triangles, each section presenting a rhombic face (fig. 9).

The first section supplies the following forms :

a. The equilateral triangle (fig. 10).

b. The equilateral triangle resting on half the adjoining triangle as a base (fig. 11).

10

11

This is a very common aspect of the half-crystal.

c. The hexagon. (fig. 12.)

d. The hexagon with the three small triangular facettes in shadow (fig. 13).

12

13

This also is a very common aspect of the half-crystal.

e. The half-triangle (fig. 14.)

f. The edge of the half-crystal tilted forward, so as to give the appearance of a triangular prism (fig. 15).

14

15

This again is a very common aspect of the half-crystal.

g. The *mâcle* or twin-crystal, formed by the partial rotation of two half-crystals on each other (fig. 16).

h. The same, with the triangular face of one half-crystal visible (fig. 17).

16

17

The second and third sections are of rare occurrence, and do not assume appearances requiring more minute description.

3. *The rhombic dodecahedron.*

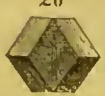
18

a. Three sides visible, so as to resemble the perspective of a cube (fig. 18).

19

b. Four sides visible, and a solid angle projected forward (fig. 19).

20



c. Five sides visible (fig. 20).

21

d. Five sides visible ; another aspect of the crystal (fig. 21).

22

e. Six sides visible (fig. 22).

23

f. The *mâcle* or twin-erystal of the rhombie dodeeahedron (fig. 23).

24

g. The *mâcle* or twin-erystal; another view (fig. 24).

Having now figured some of the leading appearanees whieh the models of the oetahedron and rhombie dodeeahedron, with their half-erystals, may be made to assume by ehanges of position, I proeeed to give a brief summary of the erystalline forms whieh I have been able to distinetly reeognise in the eourse of my examinations of the sublimates of arsenious aeid.

1. The erystalline sublimates of arsenious aeid eonsist of regular oetahedra, rhombie dodeeahedra, eubes, plates, and prisms.

2. The regular oetahedra may be entire and homogeneous, or they may be variously truneated and notehed, mottled and figured; and they may assume any of the forms depieted in figures 1, 2, 3, 4, and 5.

25

3. The entire regular oetahedron may also be modified as in the annexed engraving (fig. 25).

4. The oetahedron may present itself as a half-erystal in any of the forms depieted in figures 7 to 15, inelusive.

5. The half-erystals may be eombined to form *mâcles*, or twin-erystals, as in figures 16 and 17.

26

6. The entire erystal and the half-erystal may have their edges notehed, so as to yield figures resembling the trefoil, or *fleur-de-lis*, as in the annexed figure (fig. 26).

7. The rhombie dodeeahedron may present itself entire in any of the forms depieted in figures 18 to 22.

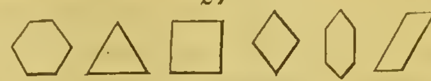
8. The rhombie dodeeahedron may present itself as a half-crystal; and two half-erystals may be united to produee the *mâcles*, or twin-erystals depieted in figures 23 and 24.

9. The eube is a very rare form among the erystals of arsenious aeid.

10. The plates present themselves as hexagons, equilateral triangles, squares, rhombs, and rhomboids; and they may be of any thiekness, from that of thin irideseent films, to the

third or the half of the diameters of the faees of the plates· They may also greatly exeeed in size the largest crystals of the groups in whieh they are found. The prineipal forms are shown in the annexed figure (fig. 27).

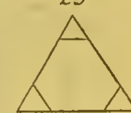
27



11. Sometimes eompound plates of large size and symmetrieal form are found united at angles eorresponding with those of the faees of the oetahedron, as in fig. 28. At other times they are grouped with great irregularity. In other instanees plates, sueh as the equilateral triangle, are found built up by a hexagonal plate symmetrieally joined to three equilateral triangles, as in fig. 29.

28

29



12. The prisms are either four-sided prisms of small size, or they are large four-sided reetangular prisms terminated by four-sided pyramids (fig. 30).

30

13. Sometimes the prisms are shorter, and present the form depieted in the subjoined figure (fig. 31).

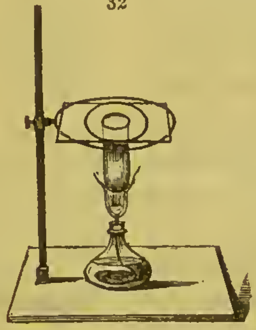
31

To this detailed deseription it is only necessary to add that there is great variety to be found in groups of erystals of arsenious aeid produeed at the same time and in the same way. In some groups the erystals are perfeet, free from spot or blemish, transparent, and brilliant; in others, notehed or truneated, mottled and figured, and translueent; in some the regular oetahedron is the prevailing form, other forms being exeeptional; in others, plates predominte, and are nearly as numerous as the erystals themselves; oeeasionally equilateral triangular plates oeeupy the whole field, to the exelusion of almost all other forms. The lithographie plate (Pl. VI) appended to the paper, and showing the sublimates as they appear by the monoeular and binoeular mieroseope, by transmitted and refleeted light, will give some idea of the variety of forms whieh the erystals assume.

The best mode of obtaining the erystals of arsenious aeid may be deseribed in a few words. The apparatus required eonsists of a spirit-lamp with small flame, speeimen tubes of small diameter and not exeeeding an ineh in length, and slides or dises of crown glass. A few grains of arsenious aeid are plaeed in a clean and dry speeimen tube, and this in a eonvenient holder, eonsisting of a slip of eopper or brass punehed or drilled to reeeive it. The tube is to be held over the flame of the lamp till the aeid collects as erystals, or as a white powder,

round the orifice of the tube. The slides or discs are then to be heated in the flame of the lamp, so as to drive off the moisture, and raise considerably the temperature, of the glass. The slide or disc, thus heated, is to be placed over the mouth of the tube, and kept there till bright spots appear on its under surface. The spirit-lamp is then to be removed, and the glass allowed to cool. The process may be conducted with the two hands over the lamp, or the holder may be supported on a retort-stand, as is shown in figure 32, and the spirit-lamp removed for a time after each operation. Good results can only be obtained when the slide or disc is heated; but if too much heat is used, the crystals are dissipated as soon as formed. When the operation is quite successful, we obtain one of the most beautiful of microscopic objects, and one of the very best illustrations of the value of the binocular microscope as a means of identification and diagnosis.*

32



* For a more detailed description of the mode of obtaining crystals of arsenious acid, consult a paper in 'Beale's Archives,' No. III, 1858, and the second edition of my 'Principles of Forensic Medicine,' in which several of the forms depicted here will be found figured.

TRANSACTIONS OF MICROSCOPICAL SOCIETY.

PLATE VI,

Illustrating Dr. Guy's paper on the Crystals of Arsenious Acid, showing the sublimates as they appear by the monocular and binocular microscope by transmitted and reflected light.

Fig. 1.

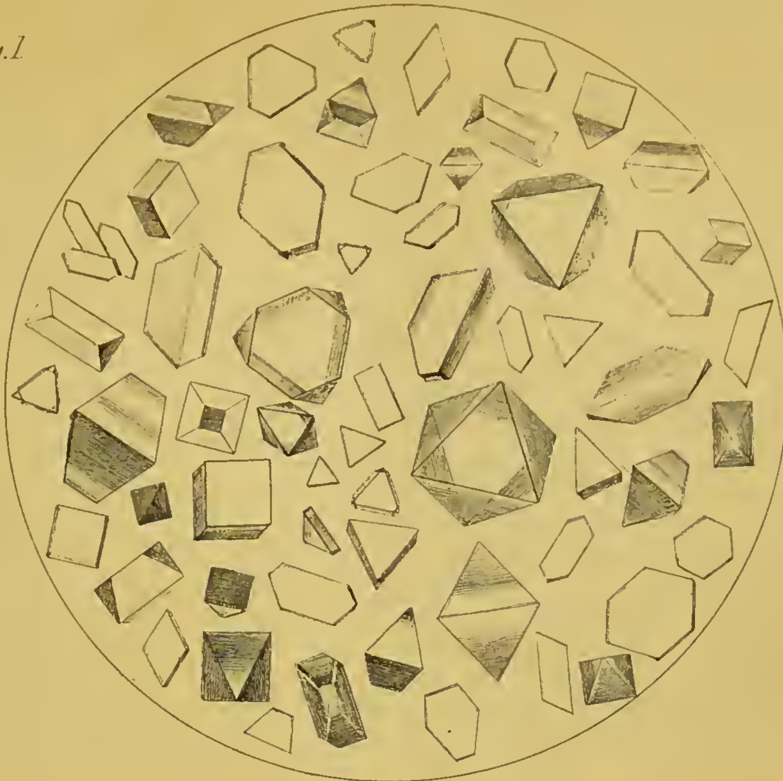
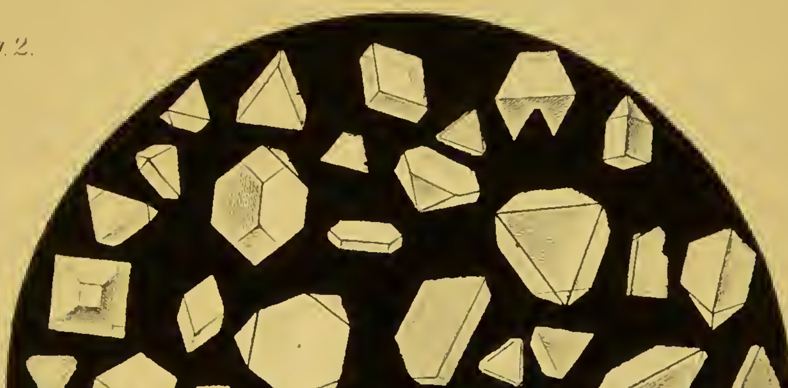


Fig. 2.



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